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Umbilical Design

Alan Littlefield / NE-D

August, 2007

Umbilical Design

- About Me - School:
  - BS Mechanical Engineering, Florida Tech, 1982
  - MS Mechanical Engineering, Florida Tech, 1987
- About Me – Work:
  - 22 years in Design Engineering
    - 2 years in Facilities Engineering
      - HVAC
      - Cranes
    - 18 years in Launch Accessories / Mechanical GSE Design
      - Umbilicals
      - Access Arms / Equipment
      - Handling Equipment
      - Test Facilities
      - Cryogenics
    - 2 years in Systems Engineering and Integration

Umbilical Design

- About Me – Programs / Projects:
  - KSC / CCAFS Facilities
  - Space Shuttle
  - Space Station GSE
  - X-33
  - Experimental / Test Facilities
  - Flight Hardware Design
- About Me – Umbilicals Experience
  - Shuttle SRB Joint Heater Umbilical
  - Shuttle Tail Service Mast
  - Shuttle ET GH2 Vent
  - Shuttle ET GO2 Vent
  - Shuttle Orbiter Mid-Body Umbilical
  - Rise-Off Umbilical Prototype
  - X-33 Umbilicals
  - Mars Umbilical Technology Demonstrator

T-0 Umbilical Types

- Rise-off (Bottom Mount)
  - Shuttle SRB Joint Heater
- Side Mount:
  - Tilting
    - Tail Service Masts (TSM)
      - Shuttle TSM
    - Long Masts
      - Redstone
    - Tilt-Up
      - Apollo TSM
    - Drop
  - Swing
    - Apollo Forward Umbilicals
  - "Pull Off"
    - Delta IV ECS

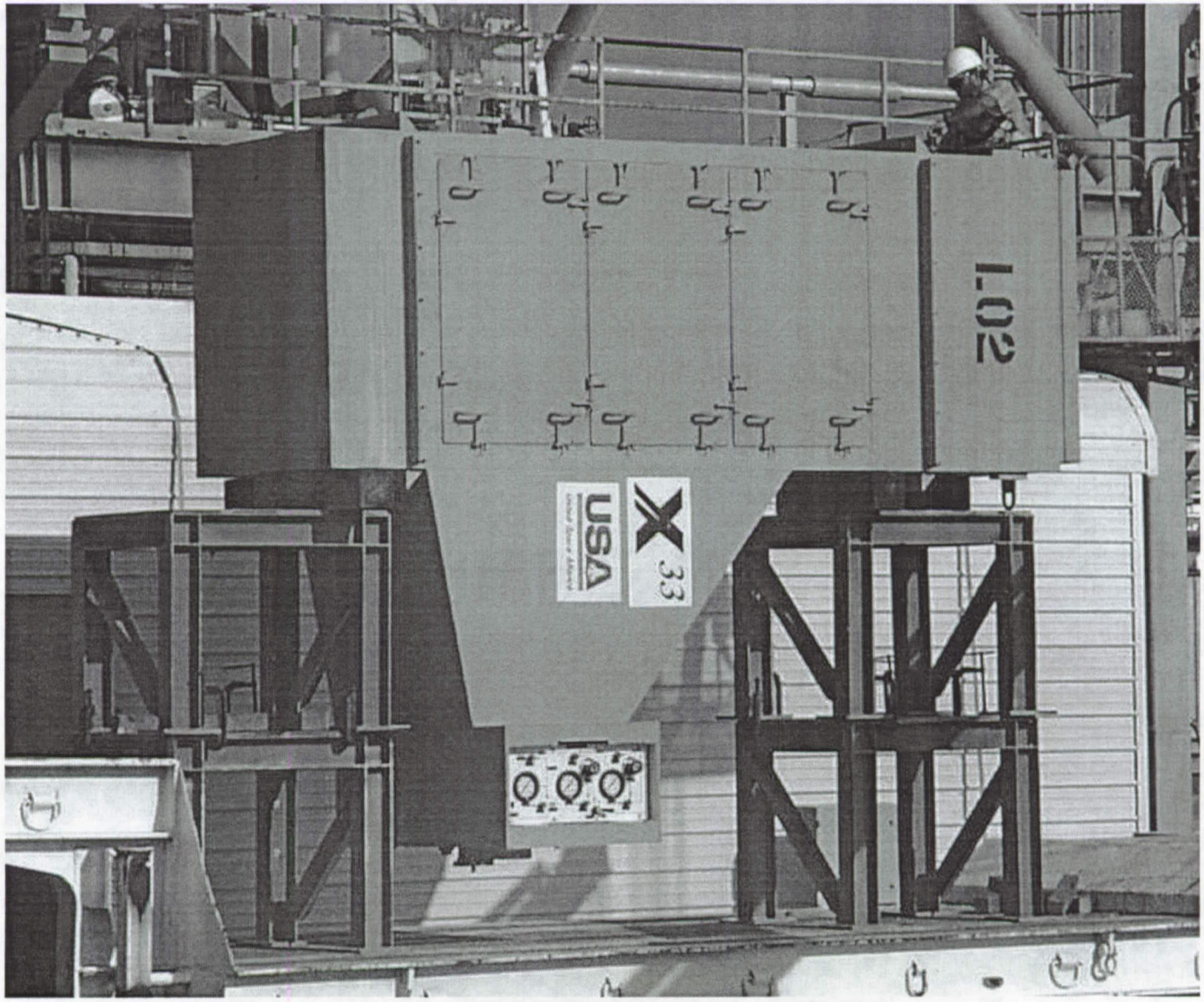
Umbilicals

- Umbilicals Typically Provide Commodities to a Launch Vehicle or Spacecraft.
- Different Types of Umbilicals
  - Ground to Ground
  - Ground to Flight (Focus of this Presentation)
  - Flight to Flight
- Typically T-0 Connections
  - Non T-0 are Typically Service Connections
- Commodities
  - Liquid Fuels / Oxidizers
  - High Pressure Gases
  - ECS
  - Power
  - Data
  - HazGas Sense

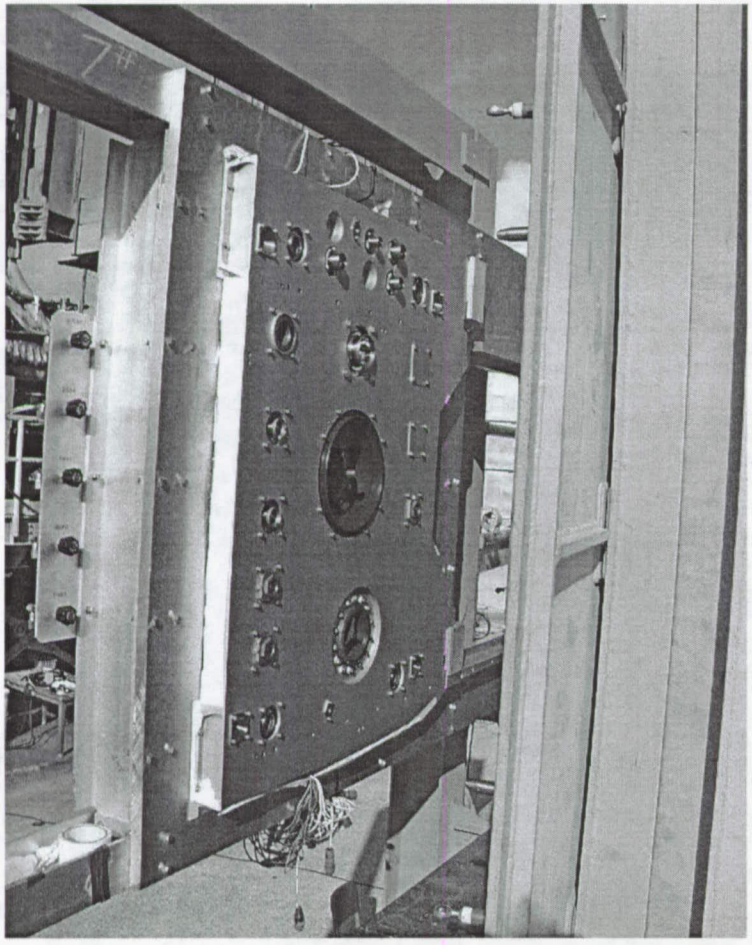
T-0 Umbilical Terminology

- Flight Carrier Plate:
  - Mechanical assembly grouping multiple individual connectors and attach and release mechanisms.
- Ground Carrier Plate:
  - Mechanical assembly grouping multiple individual connectors and attach and release mechanisms, also provides attachment to ground systems.
- Compliance Device or Mechanism:
  - Allows relative motion between vehicle and ground.
- Release Mechanism:
  - Disconnects flight and ground connectors or carrier plates.
- Retract Mechanism:
  - Withdraws ground connector or carrier plate to safe area following disconnect.
- Excursions:
  - Motions of vehicle prior to lift-off
- Drift:
  - Motions of vehicle following lift-off

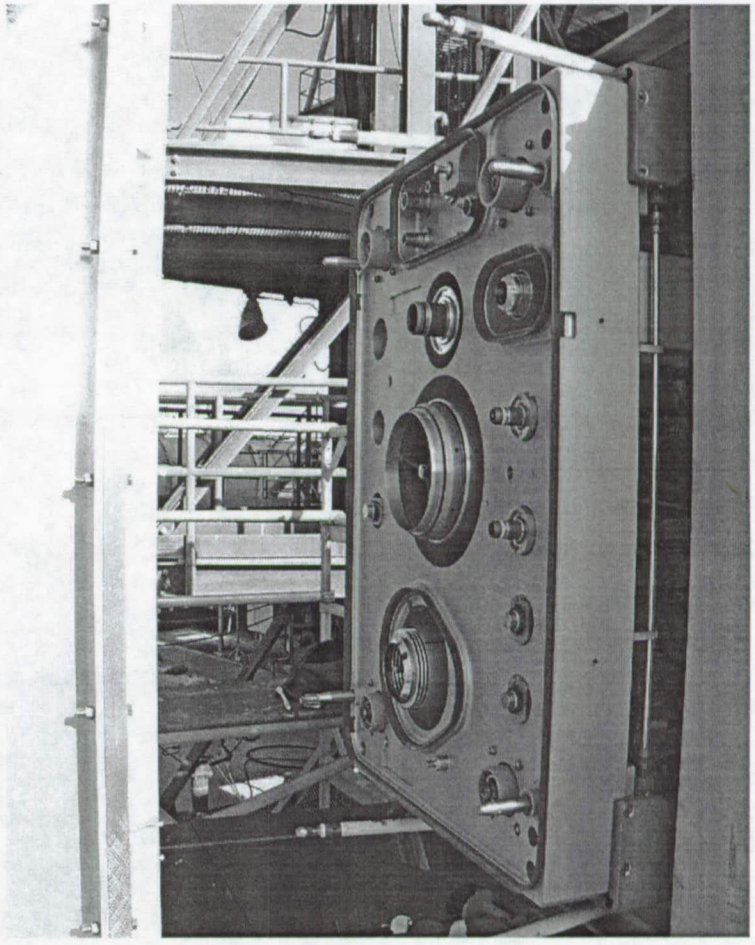
T-0 Umbilical, X-33



T-0 Umbilical Plates



Flight Panel

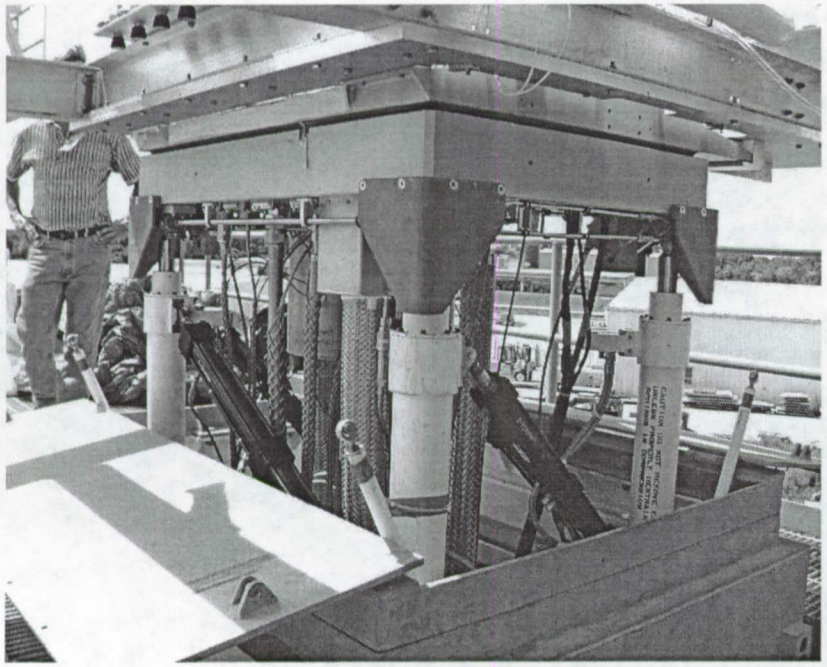


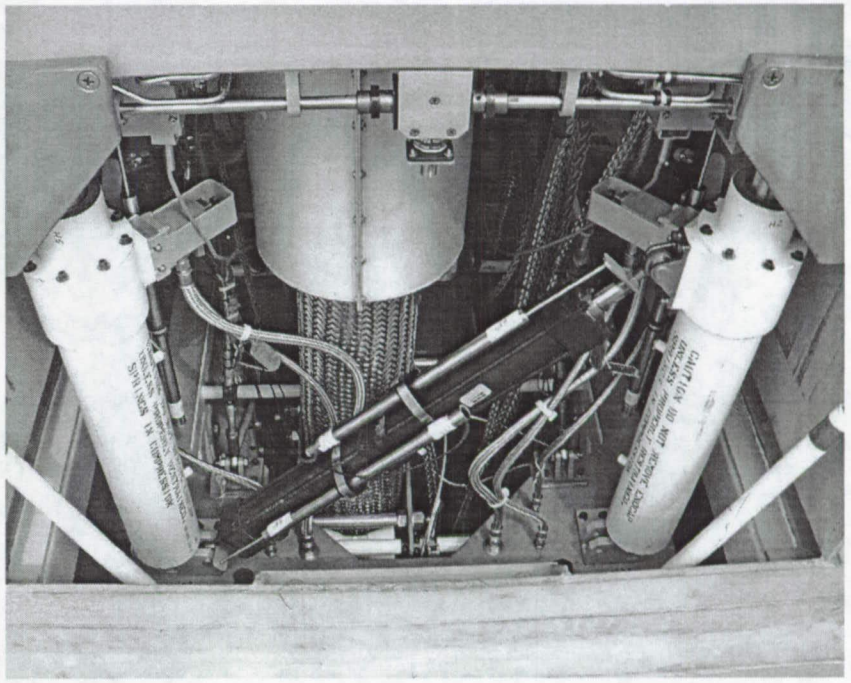
Ground Panel

T-0 Umbilical Components

- Struts
  - Main / Compliance
  - Mating
  - Centering
- Collets / Receptacles
- Shear Pins
- Feet / Receptacles (Perches)
- Shock Absorbers / Energy Absorbers
- Drop Weights
- Pryrotechnics
- Non Explosive Actuators
- Frangible Components
- Lanyards
- Blast Doors
- Latches

T-0 Umbilical Components





T-0 Umbilical Design Considerations

- Fault Tolerance / Failure Modes
- Vehicle Loads
- Connector Loads / Alignment
- Disconnect Dynamics
- Line Management
- Leakage
- Hazardproofing
- Excursions
- Trajectories / Drift
- Blast / Induced Environments
- Natural Environments
- Cryogenics / Shrinkage

T-0 Umbilical Design Considerations

- Fault Tolerance / Failure Modes
  - Fail Operational, Fail Operational, Fail Operational Where Practical
    - Particularly for Disconnect
    - Also for Attachment
  - Simplicity
  - Reliability
  - Like vs Unlike Redundancy

T-0 Umbilical Design Considerations

- Vehicle Loads
  - Typically Very Limited
  - Mating
  - Tanking
  - Disconnect
    - Primary
    - Secondary
  - Shear
  - Tension

T-0 Umbilical Design Considerations

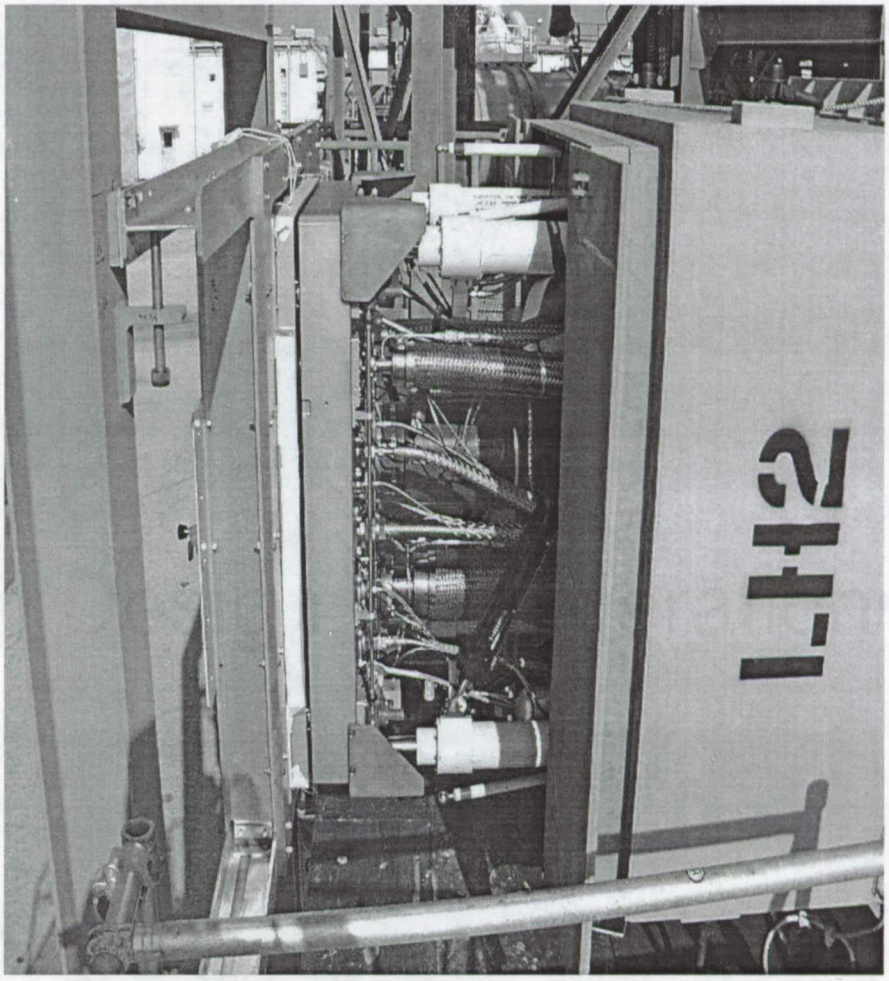
- Connector Loads
  - Mating (Static)
  - Pressurization (Dynamic)
  - Can be Significant – Kips
  - Best if Balanced on Plate
- Connector Alignment
  - Axial
  - Lateral
  - Angular
    - Static
    - Rotational (Mating or Disconnect)
  - Fluid vs Electrical
- Deadfacing / Depressurization

T-0 Umbilical Design Considerations

- Disconnect Dynamics
  - Clearances
    - Dynamic Envelope
    - Drift
  - Timing
    - Primary
    - Secondary
  - Retraction
  - Deceleration
  - Protection / Covers

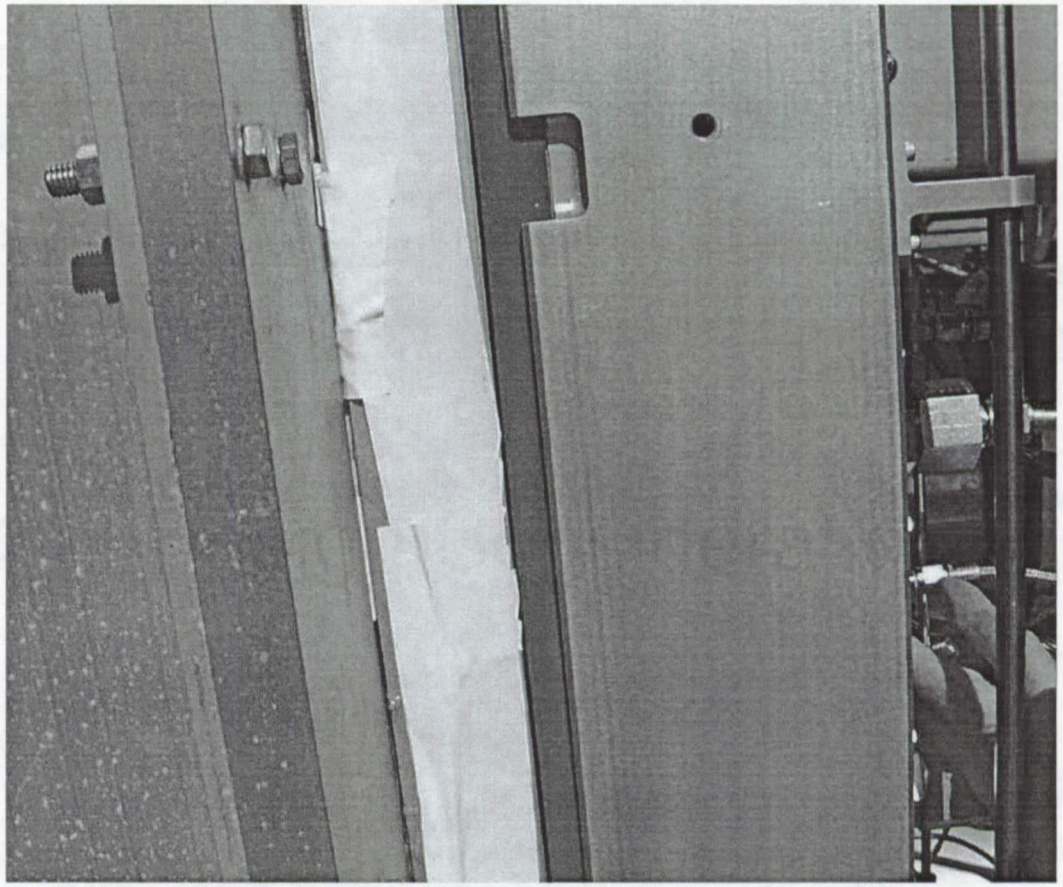
T-0 Umbilical Design Considerations

- Line Management
  - Loads
    - Bend Radii
    - Torsion
  - Tangling
  - Function
    - Drainage
    - Kinking
  - Protection



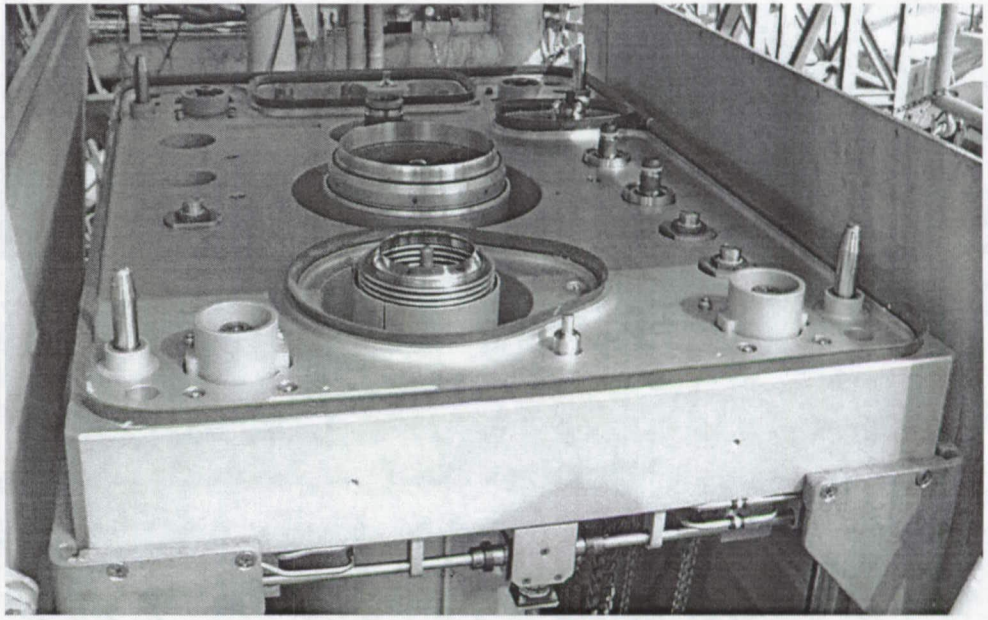
T-0 Umbilical Design Considerations

- Leakage
  - Ambient
  - Cryogenic
  - Alignment
  - Preload
  - Monitoring



T-0 Umbilical Design Considerations

- Hazardproofing
  - Purges
  - Purge Cavities / Isolation
  - Arrangement / Grouping
  - Sparking
  - Deadfacing
  - Drainback / Sweep Purges
  - HazGas Detection / Leakage



T-0 Umbilical Design Considerations

- Excursions
  - Mis-alignment or Relative Motion Between Umbilical and Vehicle
  - Excursions Vary by Operations Mode – Mating, Tanking, Abort, etc.
  - Static Excursion "Types"
    - Stacking Tolerances
    - Vehicle Manufacturing Tolerances
  - Dynamic Excursion "Types"
    - Thermal Movement
    - Wind Induced Oscillation
    - Payload Installation
    - Tanking / Cryo Shrinkage
    - Engine Buildup / Shutdown
    - Launcher / Tower Deflections

T-0 Umbilical Design Considerations

- Trajectories / Drift
  - Motion of the Vehicle after Lift-Off
    - Nominal Trajectory
      - Misc. Dispersions
      - Delays ("lift-off" not at T-0)
      - Wind / Drift
      - Other Environmental
      - Payload Variations
    - Off Nominal Trajectories
      - Vehicle Failures
      - Engine "Out" Conditions
    - Avoid Re-Contact

T-0 Umbilical Design Considerations

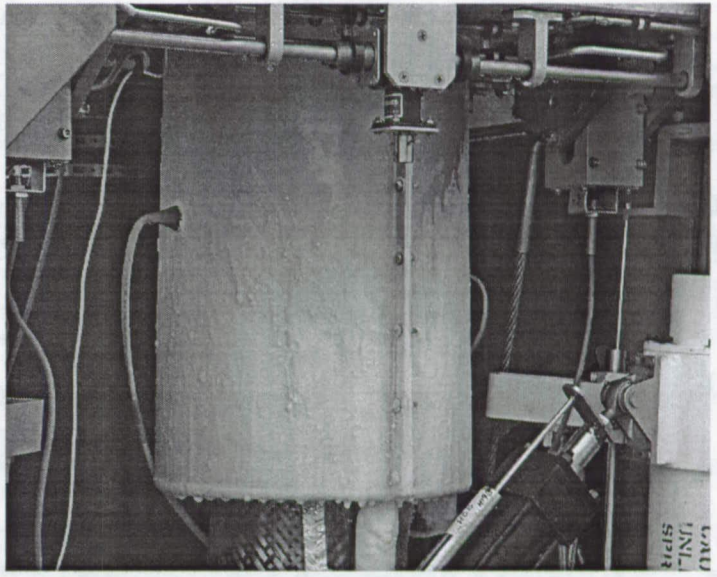
- Blast / Induced Environments
  - Blast Loads May Be Significant
    - Time to Protect Umbilical Varies
    - Pressure
      - Gas
      - Particle
        - » Erosion
    - Radiant Heating
    - Vibration
      - Pre-Launch
      - Post Launch
    - Ignition Over-Pressure
    - Acoustics / Vibro-Acoustics

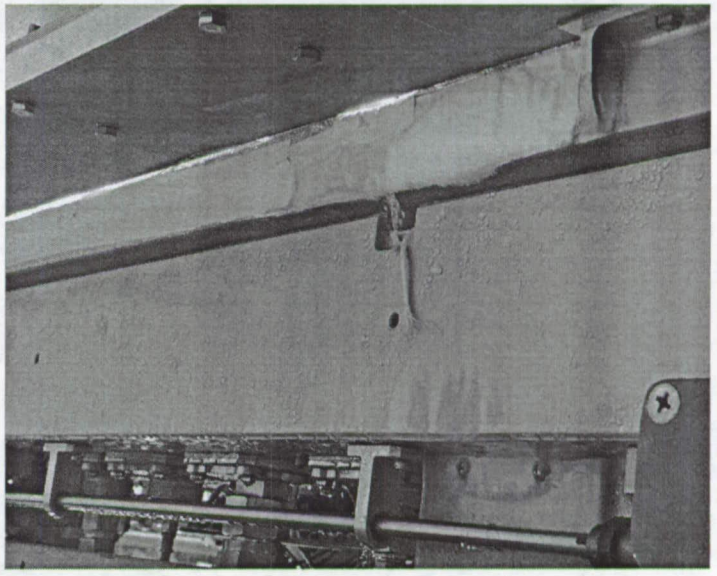
T-0 Umbilical Design Considerations

- Natural Environments
  - Rain
    - Water Intrusion
    - Ice Formation
  - Wind
    - Wind Driven Rain
  - Temperature / Humidity / Corrosion

T-0 Umbilical Design Considerations

- Cryogenics / Shrinkage
  - Temperature Control / Insulation
    - Ice / Frost
    - Liquid Air
    - Purge
      - Thermal Control
      - Humidity Control
    - Shrouds
  - Thermal Distortion
  - Thermal Gradients
  - CTE Mismatch

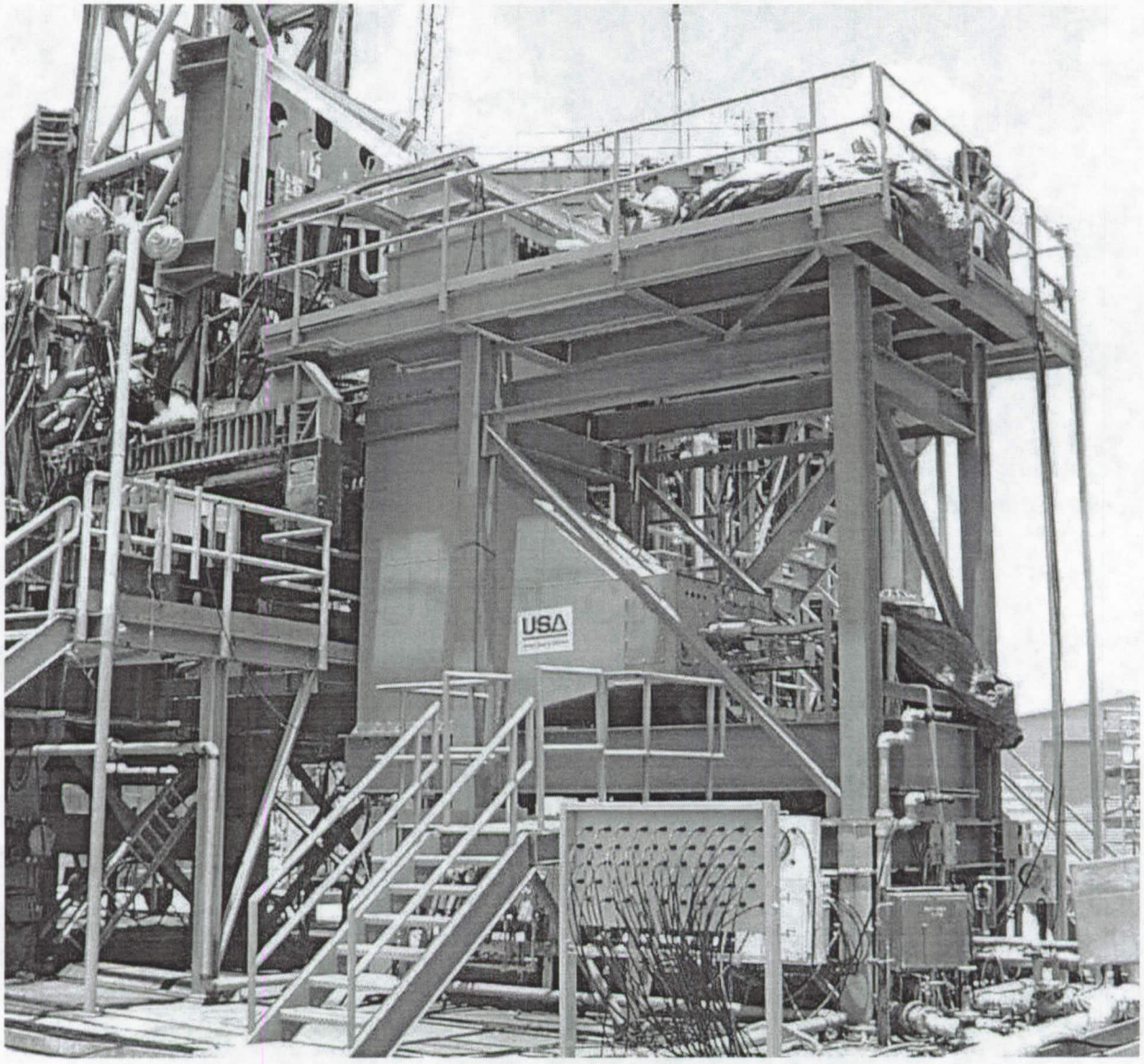




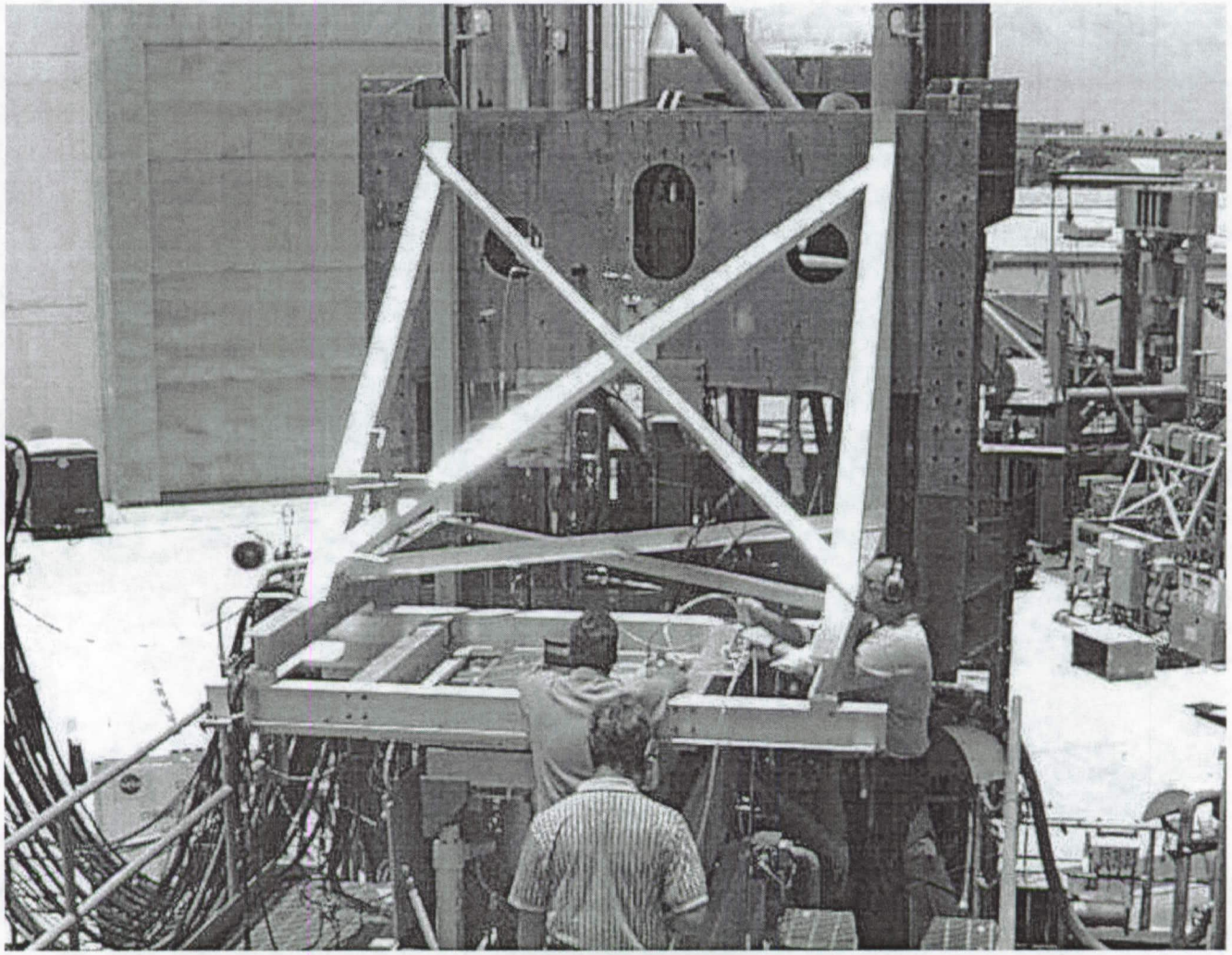
T-0 Umbilical Testing

- Development Testing
  - Prototypes
  - "Proto-Flight"
  - Breadboard
- Qualification Testing Typically Performed in Launch Equipment Test Facility
  - GSE
    - Actual GSE Prior to Shipment
    - Similar GSE Prior to Shipment
    - Prototype GSE / LETF Dedicated GSE
  - Flight Plates
    - Dedicated LETF Plates
    - Actual Flight Plates
- Validation Testing Performed on Launcher or at Pad
  - Uses Actual GSE in Launch Configuration
  - Flight Hardware Options
    - None
    - TSE
    - Pathfinder / "Iron Bird"
    - Flight Vehicle

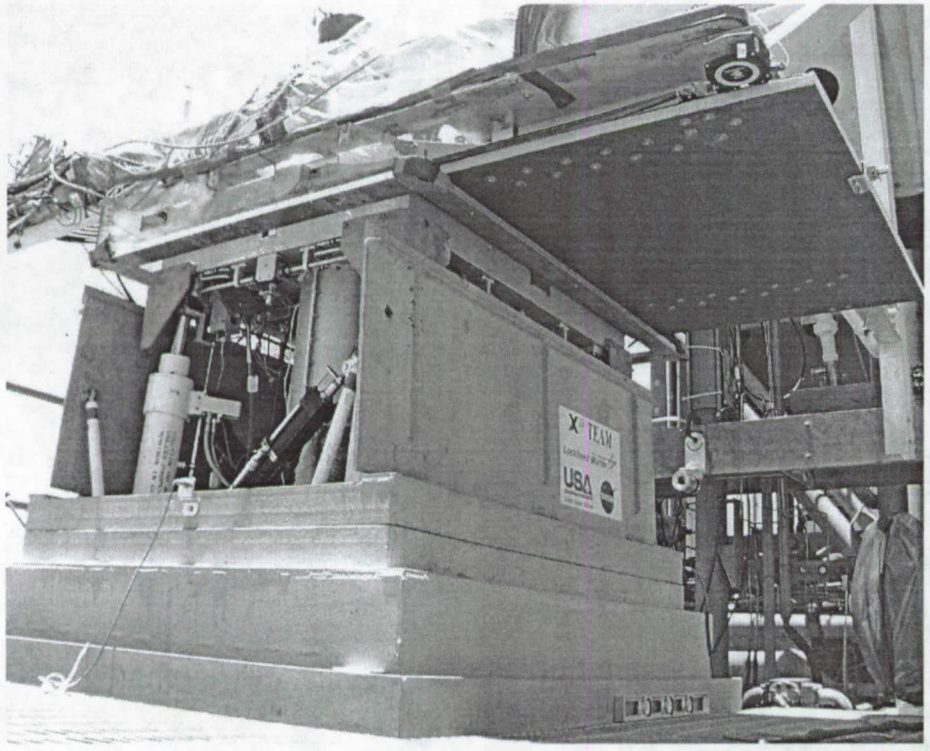
T-0 Umbilical Testing

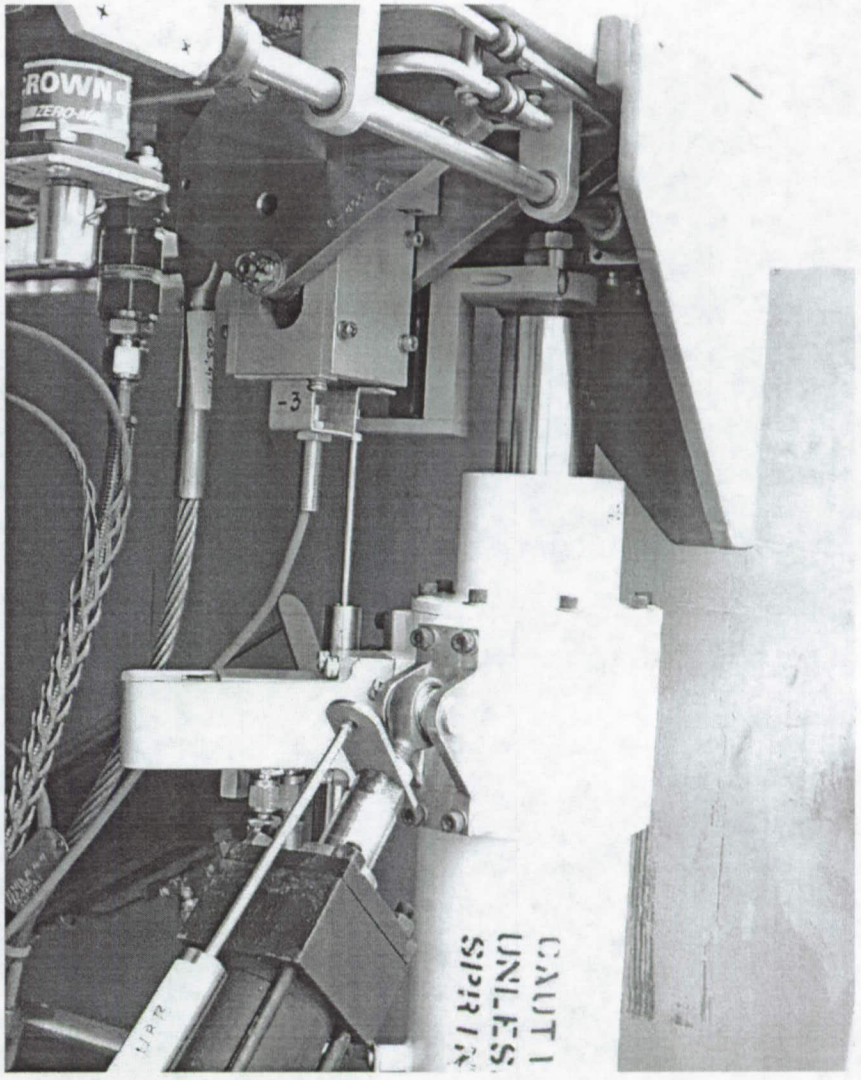


T-0 Umbilical Testing



T-0 Umbilical Testing





T-0 Umbilical Testing

- Test Objectives to Simulate Processing / Pad Operations
  - Mating
  - Pad Stay
  - Tanking
  - Build-up
  - Abort / Shut-Down
  - Launch
    - Primary Disconnect
    - Failure Modes
- Tests Included:
  - Static Excursions
  - Dynamic Excursions
  - Lift-Off / Drift
  - Cryogenic Operation
  - Wind
  - Rain
- Tests Excluded:
  - Blast / Heat (Induced)
  - Vibration
  - Acoustics
  - Heat / Cold (Natural)